

Dynamic Planet C

BirdSO Mini, December 2021

Answer Key

Directions:

- You will have 50 minutes for the entire event.
- You may use a binder, but this test is **not** open internet. It is recommended that you have a calculator.
- This test is worth 148 points. Try to complete as much of the event as possible.
- There are 10 sections with questions of varying topics and difficulty. It is recommended to look through all sections.
- The point value of “select all that apply” questions may or may not be equal to the number of correct answers.
- Tiebreakers are marked in the test in the order they will be broken (e.g., “TB1” is the first tiebreaker, “TB2” the second, etc.)

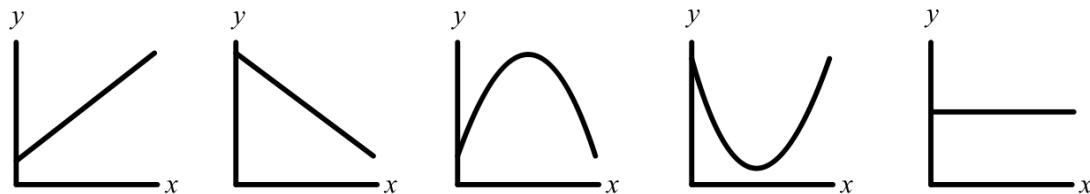
Section 1: Multiple Choice/Multiple Select (37 pts)

Multiple choice questions are 1 pt each. Multiple select (“select all that apply”) questions are 2 pts each, and may have one or more than one correct answer.

1. Rank the average particle size of the following stream loads from smallest to largest.

- 1 - bed load
 - 2 - suspended load
 - 3 - dissolved load
- a. 1, 2, 3
 - b. 1, 3, 2
 - c. 2, 1, 3
 - d. 2, 3, 1
 - e. 3, 1, 2
 - f. 3, 2, 1

2. Which of the following graphs, if any, best shows the relationship between the radius of sediment particles versus increasing depth in the middle of a lake?



(A)

(B)

(C)

(D)

(E)

- a. A

- b. B

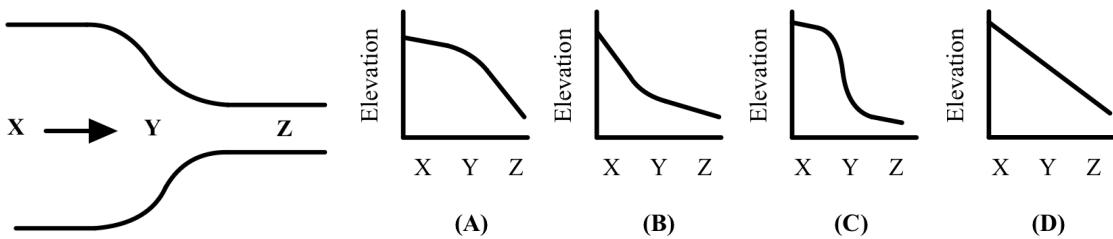
- c. C

- d. D

- e. E

- f. No distinct relationship; lake deposits are often poorly sorted

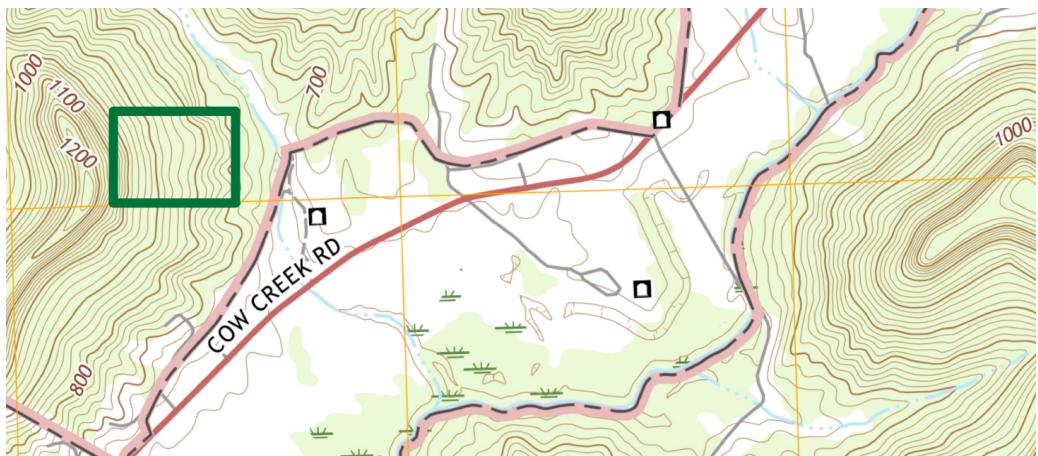
3. [TB9] Consider the following map view of a river (arrow shows flow direction) with labeled points X, Y, and Z. Four possible profiles are shown.



Which topographic profile is the most accurate? Assume uniform discharge in the river.

- a. A
 - b. B
 - c. C
 - d. D
4. [TB12] Consider a hypothetical drainage system in which all first-order tributaries have identical discharges of $100 \text{ m}^3/\text{s}$. Which best describes the discharge at the start of a third-order stream (i.e., the point of a third-order stream closest upstream)? (Use Strahler stream order)
- a. Equal to $300 \text{ m}^3/\text{s}$
 - b. At least $300 \text{ m}^3/\text{s}$
 - c. At most $300 \text{ m}^3/\text{s}$
 - d. Equal to $400 \text{ m}^3/\text{s}$
 - e. At least $400 \text{ m}^3/\text{s}$
 - f. At most $400 \text{ m}^3/\text{s}$
5. Which of these conditions is most likely to result in a decrease in delta size?
- a. Increased upstream precipitation and regional uplift
 - b. Increased upstream precipitation and regional subsidence
 - c. Decreased upstream precipitation and regional uplift
 - d. Decreased upstream precipitation and regional subsidence

For questions 6-8, refer to the following topographic map. Assume the top of the map is north.



(credit: section of USGS Irvine KY Quadrangle)

6. What type of stream is featured in the map?
 - a. Perennial stream
 - b. Disappearing stream
 - c. Intermittent stream
 - d. Underground stream
 - e. Rapids

7. What type of wetland, if any, is featured in the map?
 - a. Submerged marsh or swamp
 - b. Wooded marsh or swamp
 - c. Marsh or swamp (not submerged or wooded)
 - d. No wetlands are featured

8. What is the most likely direction of groundwater flow within the green boxed area?
 - a. Towards the north
 - b. Towards the east
 - c. Towards the south
 - d. Towards the west

9. Some relatively sinuous river systems experience a sudden decrease in sinuosity. What is the most likely cause for this occurrence?
- Sudden changes in discharge, such as flooding
 - Earthquakes and tectonic events, resulting in sag pond formation
 - Landslides blocking river flow, forming a natural dam
 - Formation of oxbow lakes due to streamflow changes**
 - Tendency for more mature streams to straighten
10. Which of the following sediment types would have the greatest porosity to permeability ratio (porosity / permeability)?
- cobbles
 - clay**
 - silt
 - sand
 - gravel
11. Which of the following correctly lists water reservoirs in order of increasing percentage of Earth's total water?
- Glaciers and ice caps < Lakes < the Atmosphere < Oceans
 - Glaciers and ice caps < the Atmosphere < Lakes < Oceans
 - Lakes < the Atmosphere < Glaciers and ice caps < Oceans
 - Lakes < Glaciers and ice caps < the Atmosphere < Oceans
 - The Atmosphere < Lakes < Glaciers and ice caps < Oceans**
 - The Atmosphere < Glaciers and ice caps < Lakes < Oceans
12. Which of the following correctly lists water reservoirs in order of increasing percentage of Earth's fresh water?
- Rivers and streams < Lakes < Permafrost < Glaciers and ice caps**
 - Rivers and streams < Permafrost < Lakes < Glaciers and ice caps
 - Lakes < Rivers and streams < Permafrost < Glaciers and ice caps
 - Lakes < Permafrost < Rivers and streams < Glaciers and ice caps
 - Permafrost < Rivers and streams < Lakes < Glaciers and ice caps
 - Permafrost < Lakes < Rivers and streams < Glaciers and ice caps

For questions 13 and 14, refer to the following satellite image labeled with two locations, X and Y.



(credit: satellite image of Canyonlands National Park taken by Landsat 7 ETM+)

13. Location X is at a(n) ___ elevation compared to Location Y.

- a. Higher
- b. Lower
- c. Equal
- d. Cannot be determined

14. Which of the following statements are true regarding the process occurring near Location X?

- a. The process shortens the stream channel
- b. The process lengthens the stream channel
- c. The process is dominated by erosion
- d. The process is dominated by deposition

15. Hack's law states that the length of the longest stream in a basin can be approximated by $L = CA^h$, where L is the length of the longest stream, A is the area of the basin, and C is some constant. Assuming the exponent h to be 0.6, how many times its original length would the longest stream in a basin be if the area of the basin doubled?

- a. 0.660
- b. 0.737
- c. 1.516
- d. 2.000

16. Large forest fires can impact a region's hydrology significantly. Select all of the following statements that are true regarding their impacts.

- a. Reduction in overland flow during heavy rain events
- b. Reduction in soil moisture
- c. Reduction in infiltration capacity
- d. Reduction in transpiration rate

17. A well begins pumping groundwater at a uniform rate q_1 for time t . If the pumping rate decreases to a new uniform rate $q_2 < q_1$ for another time interval t , which of these best describes what will happen to the cone of depression? (Assume no recharge and uniform soil)

- a. An increase in its depth and a decrease in its slope
- b. An increase in its depth and a decrease in its radius
- c. An increase in its slope and a decrease in its depth
- d. An increase in its radius and a decrease in its depth

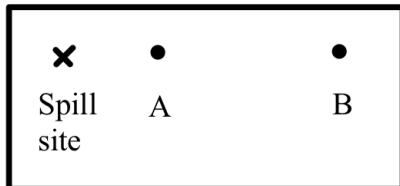
18. Which of the following correctly matches the lake to its type?

- a. Lake Baikal, tectonic lake
- b. Lake Agassiz, glacial lake
- c. Crater Lake, volcanic lake
- d. All of the above

19. Select all of the following statements that are true regarding the hydrograph for a region after it is urbanized.

- a. A larger proportion of rainwater infiltrates the ground compared to pre-urbanization
- b. A smaller proportion of rainwater infiltrates the ground compared to pre-urbanization
- c. The peak discharge after rainfall is greater compared to peak discharge pre-urbanization
- d. The peak discharge after rainfall is lower compared to peak discharge pre-urbanization
- e. The lag time between rainfall and discharge is longer compared to the lag time pre-urbanization
- f. The lag time between rainfall and discharge is shorter compared to the lag time pre-urbanization

20. A chemical spill happens instantaneously in a localized region marked by the X on the map. The edge of the plume reaches site B at $t = 10$ min after the spill. Select all of the following statements which are likely true. (Note: A_{10} = concentration of pollutant at site A at time $t = 10$ min)



- a. $A_{10} > B_{10}$
- b. $A_{10} = B_{10}$
- c. $A_{10} < B_{10}$
- d. $A_{10} > A_{30}$
- e. $A_{10} = A_{30}$
- f. $A_{10} < A_{30}$

21. Which of these can be generally assumed about the rate of pollutant transport at 10 m below the surface, v_{10} , and at 50 m below the surface, v_{50} ?

- a. $v_{10} > v_{50}$
- b. $v_{10} = v_{50}$
- c. $v_{10} < v_{50}$
- d. Inconclusive; the rates vary widely by region

22. [TB3] Consider the data table below. Each well is located at 125 m above sea level.

| Well | A | B | C | D |
|---|-----|-----|-----|-----|
| Height of piezometric surface (m above sea level) | 150 | 100 | 150 | 100 |
| Confined aquifer? | Yes | Yes | No | No |

Which well is considered an artesian well?

- a. A
- b. B
- c. C
- d. D

23. The table below describes the vegetation found at three locations.

| Location | Vegetation |
|----------|---|
| X | cypress trees, buttonbush shrubs, cattails |
| Y | sphagnum moss, water chestnut sedge, pitcher plants |
| Z | sawgrass, cattails, papyrus sedge |

Which of the following correctly classifies the three locations?

- a. X - bog, Y - marsh, Z - swamp
- b. X - bog, Y - swamp, Z - marsh
- c. X - marsh, Y - bog, Z - swamp
- d. X - marsh, Y - swamp, Z - bog
- e. X - swamp, Y - bog, Z - marsh
- f. X - swamp, Y - marsh, Z - bog

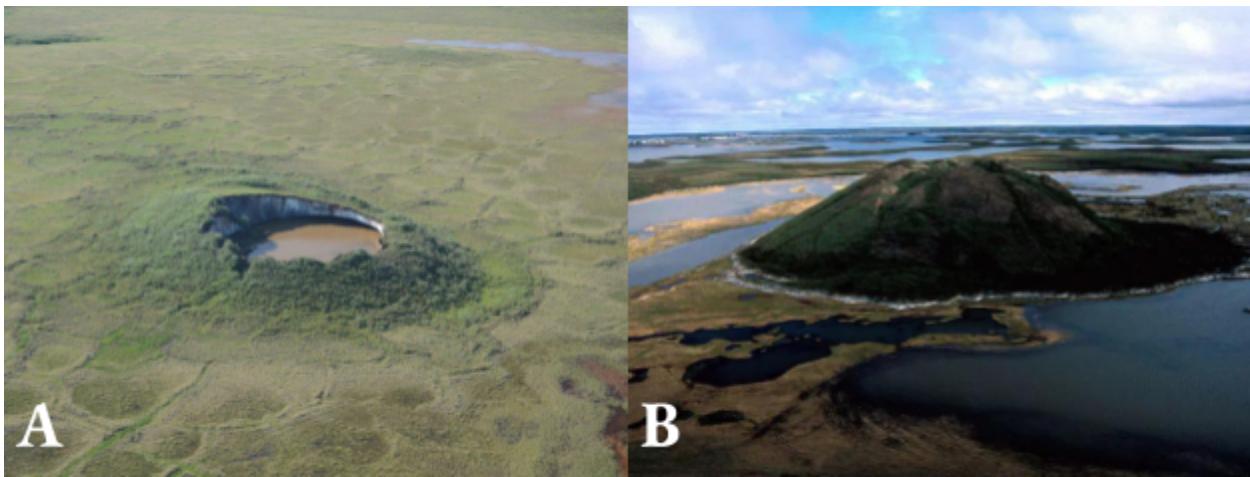
24. Select all of the following statements that are true regarding bogs.

- a. Bogs derive the majority of their water from surface water
- b. Bogs derive the majority of their water from groundwater
- c. Water flowing from bogs tends to be brown due to high peat tannin concentrations
- d. Bogs are eutrophic
- e. Bogs are oligotrophic
- f. Bogs are ombrotrophic

25. Select all of the following statements that are true regarding freshwater marshes.

- a. They are often found in high elevation areas
- b. They are characterized by moist, well-oxygenated soils
- c. They reduce the variability of adjacent streamflow
- d. Some freshwater marshes are subject to cyclic changes in water levels
- e. Diversion of water by artificial canals can lead to their decline

For questions 26 and 27, use the following images.



26. Image A and Image B represent two different stages for this feature. Which of the following correctly states the order that these stages occur and a reasonable month of the transition event?

- a. The stage in Image A transitions into the stage in Image B during January
- b. The stage in Image B transitions into the stage in Image A during January
- c. The stage in Image A transitions into the stage in Image B during July
- d. The stage in Image B transitions into the stage in Image A during July
- e. The stage in Image A transitions into the stage in Image B during November
- f. The stage in Image B transitions into the stage in Image A during November

27. Select all of the following statements that are true regarding the feature in this image.

- a. The feature forms when the soil temperature remains below 0\degree C
- b. The feature forms when the soil temperature remains below 32\degree C
- c. The open system type of this structure is found in areas with a substantial groundwater source
- d. The closed system type of this structure is found in areas with a substantial groundwater source
- e. The high specific heat of water is directly related to the formation of these features
- f. The expansion of water at low temperatures is directly related to the formation of these features

28. Which of the following statements regarding speleothems is incorrect?
- a. Stalactites hang from the ceilings of caverns
 - b. Caverns with speleothems occur within the saturated zone
 - c. Columns form when a stalagmite combines with a stalactite
 - d. Stalagmites have a hollow structure
 - e. None of the above (all statements are correct)
29. Which of the following incorrectly matches the fluvial terrace type to its description?
- a. Strath terraces form when a stream downcuts through bedrock
 - b. Unpaired terraces are terraces that exist on opposite sides of a river but are at the same elevation
 - c. Nested fill terraces form when a previously filled valley is eroded and refilled with less sediment
 - d. Fill terraces form when a valley is filled with river sediment
30. Which of the following pollution sources can be considered geogenic?
- a. Road salt causing high chloride concentrations in water bodies
 - b. Excessive fertilizer use causing high nitrate concentrations
 - c. Uranium in bedrock decaying to release radon
 - d. Leachate from landfills seeping into aquifers
 - e. Improperly designed septic tanks allowing bacteria to enter groundwater

Section 2: The Hydrologic Cycle and Water Budgets (12 pts)

31. (2 pts) Select all of the following true statements about the hydrologic cycle.
- a. The amount of water vapor in the atmosphere over a given region remains constant.
 - b. Due to global warming, the hydrologic cycle is slowing down.
 - c. The formation of fog over a warm lake is an example of evaporation.
 - d. Out of all precipitation falling on Earth's surface, most falls onto the oceans.
 - e. Energy from the Sun is the only major source of energy driving the hydrologic cycle.
 - f. During periods of light rain, it is possible for there to be zero runoff.

32. (3 pts) [TB5] Is the net seaward flux (towards the sea) of atmospheric water vapor positive, negative, or zero? Justify your answer.

Negative (+1 pt). There is an imbalance between evaporation and precipitation over land and over the ocean. Specifically, $E > P$ over the ocean, and $P > E$ over land. Runoff and infiltration overall carries water from land to the sea, and since mass is conserved in the hydrologic cycle, the net flux is landward/away from the sea in the atmosphere. (+1 pt for mentioning imbalance between E and P , +1 pt for mention of mass balance/mass conservation)

*Note: since the question could be interpreted differently than intended, +2 pts can be given for $E > P$ over ocean, most water entering the oceans is in the liquid phase, there is a net transport of water vapor from above the oceans to over land

Suppose you are hiking on a tall, snowy mountain and notice that a snowfield has shrunk noticeably in size in the past few hours with very little meltwater.

33. (0.5 pt) Identify the process in the water cycle responsible for this observation. (Hint: what happened to the snow that didn't melt?)

Sublimation

34. (0.5 pt) Indicate whether the process involves an absorption of heat energy, a release of heat energy, or neither.

- a. absorption of heat energy
- b. release of heat energy
- c. neither

Water budgets can be used to model the hydrologic characteristics of a region. Let P = precipitation, ET = evapotranspiration, R = runoff, and I = infiltration.

35. (1 pt) For the hydrologic cycle on Earth overall, select all of the below expressions that correctly compare the quantities above.

- a. $P > (R + I)$
- b. $(R + I) > ET$
- c. $ET > I$
- d. $(ET + R) > P$

36. (1 pt) In terms of P , R , and I , write an expression equivalent to the fraction of precipitation that undergoes evapotranspiration.

$$(P - R - I)/P \text{ (half credit given for correct numerator)}$$

A researcher models annual lake volume fluctuations of an ephemeral lake. Assume the lake is not connected to any surface streams. In the model, precipitation P and evaporation E (calculated in L/h) are assumed to be the only inputs and outputs, respectively, to the lake.

37. (2 pts) [TB11] The researcher wants to find the change in lake volume ΔV over time by graphing. What quantity should be plotted on the y -axis vs. time, and how can the graph be used to find ΔV ?

Plot $(P - E)$ or precipitation minus evaporation (+1 pt), then find the area under the curve (+1 pt)

*Partial credit: multiply $(P - E)$ by time (+1.5 pts total - although not technically correct since $(P - E)$ is unlikely to be constant)

*Partial credit: plot volume vs time, then subtract initial or earlier volume from the final or later volume (+1 pt) (not the slope since that would be $\Delta V/\Delta t$ or dV/dt , not ΔV)

38. (2 pts) Are the actual lake levels likely to be higher, lower, or approximately equal to the modeled lake levels? Briefly justify your answer.

Lower (+1 pt), since an additional output is the discharge of lake water into the surrounding groundwater / infiltration (+1 pt). (Accept other specific valid outputs, such as consumption of lake water by animals/humans or transpiration from nearby plants)

[Note that it is not likely for the reverse to happen (groundwater flowing into the lake), since the lake is ephemeral, so the climate is likely to be dry and the water table is likely below the lake]

Section 3: Floods and land use (10 pts)

39. (2 pts) Flood safety is important! Identify all of the following true statements, if any.
- a. It is generally safe for a car to pass through a foot of flowing water.
 - b. Flash flooding is generally more likely to occur in fields than urbanized surfaces.
 - c. A few inches of rain can raise the stream level by a few feet or more.
 - d. Floodwaters are not safe to consume due to hazardous contaminants that may be present.
 - e. None of these are true.
40. (2 pts) [TB4] A 25-year flood occurred in a town in 2021. Based on the information, which of the following statements is/are true about flooding risk in that town, if any?
- a. The next 25-year flood will not occur until 2046.
 - b. The next 25-year flood is expected to occur before 2046.
 - c. Multiple 25-year floods can occur before 2046.
 - d. It is possible for a flood of the same severity to be classified as a 10-year flood in the future
 - e. None of these are true.
41. (2 pts) Based on the previous question, calculate the probability (to the nearest percent) of a 25-year flood in the period 2022 to 2026. Show relevant equation(s) and calculation steps.
Using $P_t = 1 - (1 - P_e)^t$ where $P_e = 0.04$ and $t = 5$, $P_t = 18\%$ (accept 0.18)
(+0.5 pt for equation, +0.5 for correct P_e value (as part of a calculation, not final answer), +0.5 for correct t value, +0.5 for correct answer with work shown)
42. (2 pts) Studies have mixed results regarding the effect of urbanization on base flow volume. Select all of the following that would support the hypothesis that base flow decreases due to urbanization.
- a. Some cities have higher rates of water consumption than surrounding areas.
 - b. Vegetative cover is associated with significant evapotranspiration in an area.
 - c. In a certain region, it is found that a high proportion of base flow is sourced directly from groundwater.
 - d. Discharge from urban streams is found to be higher than that from non-urban streams during periods of no precipitation.

43. (2 pts) Some fish species lay their eggs in sediment. Briefly describe how artificial channels affect the stream and reduce their survivability.

Artificial channels increase the flow velocity of the stream (+1 pt), causing the erosion of sediment containing the eggs (+1 pt)

Other acceptable effects on stream: artificial channels can cause channel switching, increases stream discharge, increases suspended sediment load, decreases channel sediment

Other acceptable reduced survivability explanations: reduction in available/accessible habitat, sweeping away of eggs by a faster river, physical damage to fish eggs (not just “harm” them), increased susceptibility of eggs to predators due to exposure

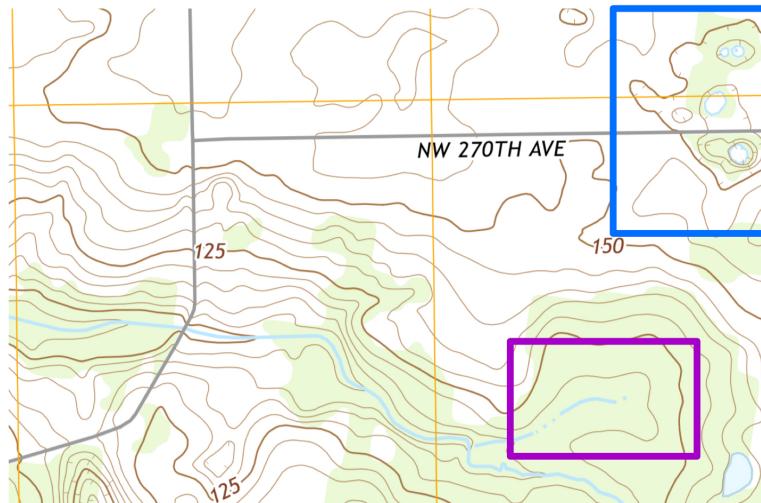
Section 4: Karst hydrology (12 pts)

44. (3 pts) [TB2] Let $q_{\text{surf}}/q_{\text{sub}}$ be defined as the ratio of surface discharge to subsurface discharge. Is it expected for a karst region to have a high or low value of $q_{\text{surf}}/q_{\text{sub}}$ relative to non-karst regions? Identify a common karstic rock type, then briefly describe how a property of the rock relates to your answer to the first question.

Low value (+1 pt), because karst landscapes usually contain limestone/carbonate/evaporite rocks (+1 pt for rock unit identification, naming minerals are not accepted) that dissolve easily and/or that have relatively high permeabilities/porosities (+1 pt for physical property) allowing for increased underground discharge or disrupted surface drainage.

(Sidenote: technically limestone's permeability varies based on whether it's fractured or not, but cavernous/fractured limestones are fairly common in karst landscapes)

For questions 45-46, consider the topographic map below. Assume the top of the map is north.



(credit: section of USGS Mikesville FL Quadrangle)

45. (2 pts) What karstic features are located in the blue box? What is the meaning of the USGS topographic map symbols used to depict these features? (Hint: They are different.)

Sinkholes (+1 pt) OR solution valley, lake/pond (+0.5 pt).

The symbols indicate depressions/basins (+1 pt).

46. (2 pts) A student claims that the feature in the purple box is a disappearing stream. Is the student correct? Briefly discuss the evidence in the map that led to your answer and state the direction of flow, if any, of the feature.

No (+0.5 pt). The stream flows towards the west/southwest into another stream (+0.5 pt). According to the map, the elevations are lower towards the west OR the contour lines point east/in the opposite direction of flow OR the topographic map symbol for a disappearing stream is absent (+1 pt for valid supporting evidence).

***Note: A stream can both be intermittent and disappearing; a valid justification clarifies that the disappearing stream symbol is absent.

47. (1 pt) Suppose the • symbol were present near the easternmost end of the feature. Would that suggest the presence of an underground stream? Interpret the meaning of the symbol.
Yes; the symbol represents a spring/seep (+0.5 pt each)

48. (2 pts) What hazard besides pollution could groundwater withdrawal pose in a karst region?

Briefly describe one way withdrawing groundwater could lead to this hazard.

Withdrawing groundwater increases the risk of sinkhole collapse or landslides or ground subsidence (+1 pt), due to reduction in soil moisture/lowering of the water table or reduced soil cohesion or reduced stability (+1 pt for any of these reasons). Partial credit: +0.5 pts for more erosion or water scarcity.

49. (1 pt) In a karst region, an empty cavern is located in the zone of ____ and indicates a water table that was previously ____ than the present.

- a. aeration; higher
- b. aeration; lower
- c. saturation; higher
- d. saturation; lower

50. (1 pt) Which of these chemical properties is characteristic of karstic lakes?

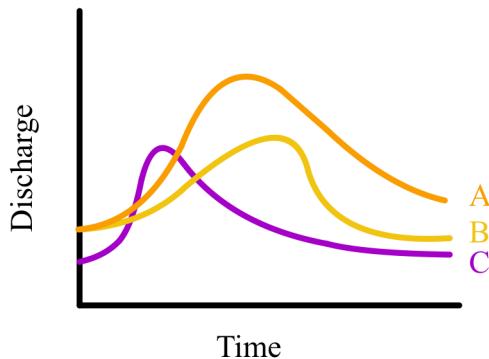
- a. High salinity
- b. Low salinity
- c. High alkalinity
- d. Low alkalinity

Section 5: Going with the flow (15 pts)

Hydrographs can be used to model stream flow by plotting discharge versus time.

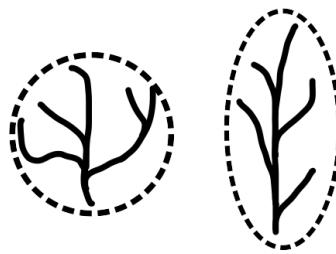
51. (2 pts) Refer to the sample hydrographs shown below. A brief downpour occurs at $t = 0$.

Which hydrograph (A, B, or C) is least realistic? Briefly justify your answer.



Graph B (+1 pt), because the falling/recession limb is steeper than the rising limb OR B has the longest lag time (+1 pt).

The two drainage basins shown (D and E) have equal areas and similar characteristics; they differ only in their shape (shown by the dotted outlines). Assume that a rainstorm drops the same amount of precipitation across both basins.



Basin D Basin E

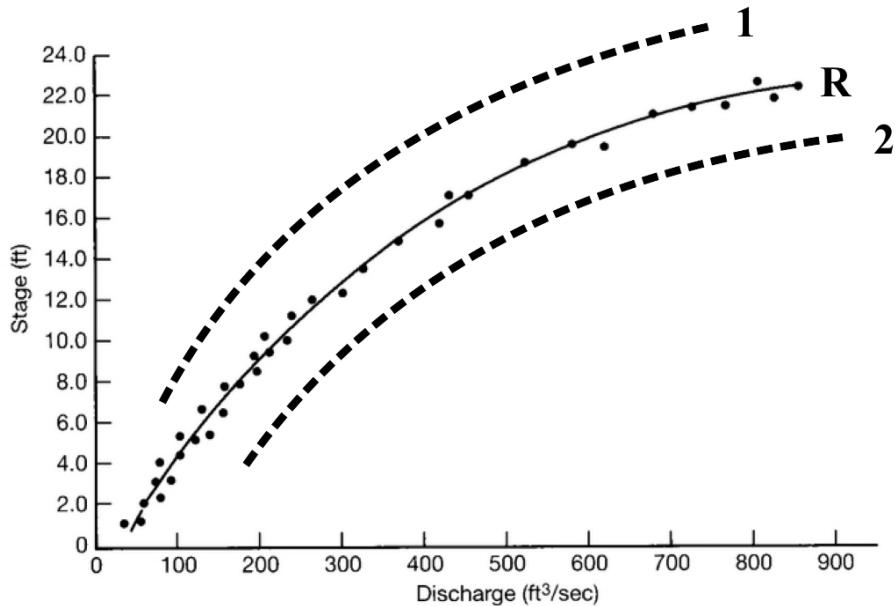
52. (1 pt) Which basin will have a longer lag time?

- a. Basin D
- b. Basin E
- c. Neither

53. (1 pt) Which basin will have a higher peak on its hydrograph?

- a. Basin D
- b. Basin E
- c. Neither

Rating curves, graphs of stage versus discharge, can also be used to model stream flow. Stage is the water level measured from some arbitrary reference point.



(adapted from Sanders 1998)

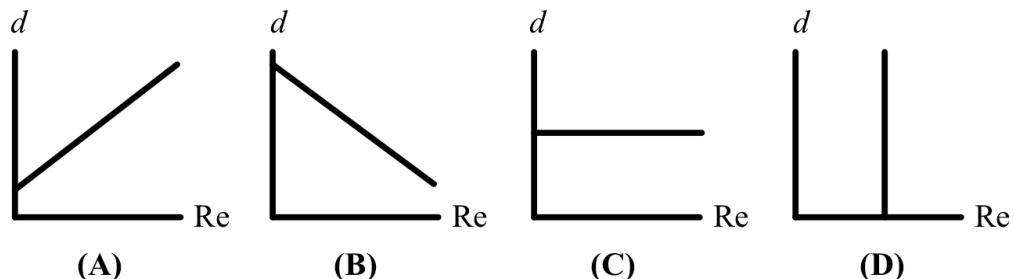
54. (1 pt) Consider the solid curve labeled "R." At a stage of 12 ft, what is the approximate discharge, in ft^3/s , of the stream?

Accept any answer from 250 to 300

55. (2 pts) [TB1] If the stream's width increases, and all else remains equal, would curve 1 or curve 2 represent the new curve? Briefly justify your answer.

Curve 2 (+1 pt). At the same discharge/volume, the stage/water height would be lower; at the same stage, the discharge would be greater (+1 pt for either).

The Reynolds number (Re) is a dimensionless quantity proportional to flow speed. In an area, there is a correlation between the Re of a river and the depth to the water table d in a nearby well.



56. (1 pt) Select the graph above that best describes the relationship.

- a. A
- b. B
- c. C
- d. D

57. (2 pts) [TB8] Explain your answer to the previous question. (Hint: State one variable that affects both d and Re , and briefly discuss how that variable affects d and Re .)

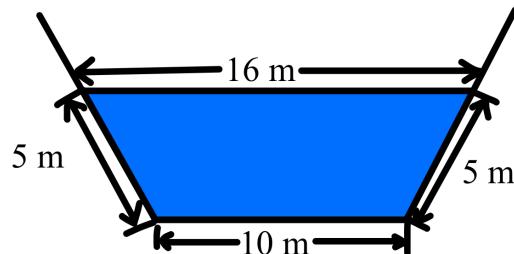
Higher Re values (more turbulent flow) and a shallow water table are associated with high precipitation. High precipitation increases river discharge and velocity and thus the probability of turbulent flow (or the Re number), and high precipitation results in a higher (shallow) water table due to increased infiltration. Other acceptable variables: amount of groundwater/hydraulic head, amount of river discharge (+1 pt for stating a variable related to both d and Re , +1 pt for explaining the variable affects water table depth AND flow pattern or Re , +0.5 each)

58. (1 pt) Does turbulent flow increase, decrease, or have no effect on the average stream velocity compared to laminar flow?

- a. Increase
- b. Decrease
- c. No effect

59. (4 pts) [TB6] Consider the following cross-section of a stream (assume that it is symmetric).

Given a Manning's roughness coefficient of $n = 0.03$ and a slope of $1/25$ (perpendicular to the cross section), calculate the discharge of the stream. Show relevant equation(s) and calculation steps.



$$v = \frac{k}{n} R^{2/3} S^{1/2} \quad (+1 \text{ pt for Manning's formula}), k = 1 \text{ or } 1.486 \text{ depending on units}$$

$$A = (0.5)(10 + 16)(4) = 52 \text{ m}^2 \quad (+1 \text{ pt for correct area calculation})$$

$$R = \text{area} / \text{wetted perimeter} = 52 / 20 \quad (+1 \text{ pt for correctly using hydraulic radius formula})$$

$Q = Av = (52/0.03) * ((52/20)^{2/3}) * ((1/25)^{1/2}) = 655 \text{ m}^3/\text{s}$ (+1 pt with correct units. Credit for a numerical answer between 650-660 m^3/s , inclusive)
(Also accept 966-981 ft^3/s , inclusive, if the conversion factor of 1.486 is used)

Alternate solution: using/substituting Chezy formula correctly:

$$52 * (1/0.03) * ((52/20)^{1/6}) * ((52/20) * (1/25))^{1/2} = 655 \text{ m}^3/\text{s}$$

If an intermediate mistake is made, the answer will receive other points as long as the other steps follow consistently and correctly from the incorrect value.

Section 6: Groundwater Day (11 pts)

Consider the data table below.

| | Well A | Well B |
|--------------------------------------|--------|--------|
| Elevation (above mean sea level) (m) | 130 | 110 |
| Depth to water table (m) | 15 | 5 |

60. (3 pts) [TB10] The walking distance from Well A to Well B is 50 m. Calculate the magnitude of the hydraulic gradient from well A to well B, rounding to the nearest hundredth. Show relevant equation(s) and calculation steps.

Change in water table height $\Delta h = (130 - 15) - (110 - 5) = 10 \text{ m}$ (+1 pt) (negative values ok).

[No point if the calculation is just $15 - 5$, which is not correct, or if no work is shown.]

Horizontal distance $L = \sqrt{50^2 - 20^2} = 45.83 \text{ m}$ (+1 pt)

$\Delta h/L = 0.22 \text{ m/m}$ (+1 pt if final answer is $\Delta h/L$, with either correct units or no units, negative values ok)

If an intermediate mistake is made, the answer will receive other points as long as the other steps follow consistently and correctly from the incorrect value.

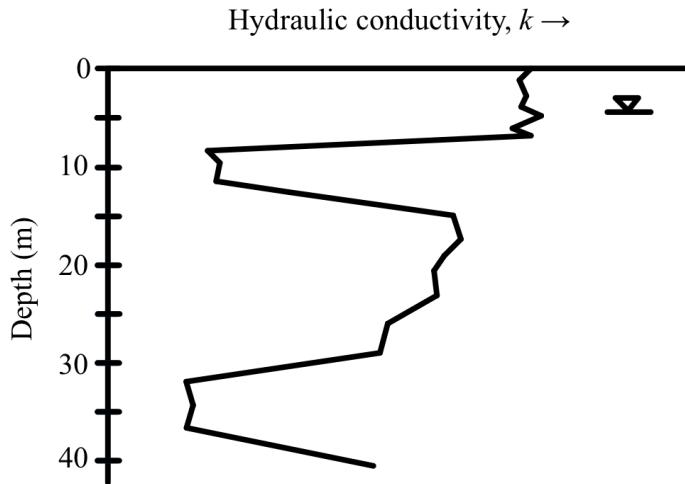
61. (2 pts) Well A is located west of Well B, which is located west of a stream. Based on the data in the table, is the stream classified as influent (losing), effluent (gaining), or neither? Justify your answer.

Effluent/gaining (+1 pt). The water table slopes downward towards the stream OR the slope indicates that the groundwater is flowing towards the stream (or there is a net flux of groundwater into the stream) (+1 pt for valid justification).

*Invalid justifications: topography/surface slopes towards the stream, depth to water table is less as one gets closer to the stream

*Partial credit: influent and an indication that water is flowing away from the wells (+1 pt - note that the question is asking about the stream, *not* the wells)

Shown below is a graph of depth vs. hydraulic conductivity (increasing values towards the right) for another well. The inverted triangle denotes the level of the water table. Use the graph for questions 3-4.



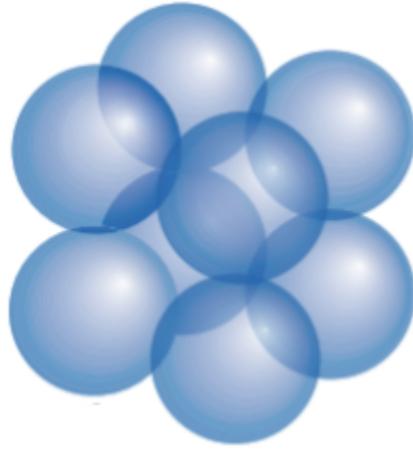
62. (2 pts) Select all of the following that can be reasonably concluded from the graph above.

- a. A confining bed exists between the depths of 0 and 5 m.
- b. A confining bed exists between the depths of 7 and 15 m.
- c. A perched aquifer exists between the depths of 0 and 7 m.
- d. A perched aquifer exists between the depths of 7 and 15 m.
- e. Assuming that the hydraulic gradient is constant, depth vs. groundwater velocity would mirror depth vs. hydraulic conductivity.
- f. Assuming that the hydraulic gradient is constant, depth vs. porosity would mirror depth vs. hydraulic conductivity.

63. (1 pt) To which depth should a well reach to maximize yield and to minimize potential for contamination?

- a. 5 m
- b. 10 m
- c. 20 m
- d. 35 m

64. (3 pts) The porosity of a rock can be expressed by the equation $\phi = \frac{V_{void}}{V_{total}}$. Use this equation to derive the porosity of the cubic packing arrangement shown below. Show relevant equation(s) and calculation steps. Round your answer to the nearest thousandth.



$$\phi = \frac{V_{void}}{V_{total}}$$

$$\phi = \frac{V_{total} - V_{solid}}{V_{total}} \quad (+1 \text{ pt})$$

$$V_{total} = 8r^3, V_{solid} = \frac{4}{3}\pi r^3$$

$$\phi = \frac{8r^3 - \frac{4}{3}\pi r^3}{8r^3} \quad (+1 \text{ pt for substitution/intermediate work})$$

$$\phi = 1 - \frac{\pi}{6}$$

$$\phi = 0.476 \quad (+1 \text{ pt for correct answer})$$

Section 7: BirdSO meets freshwater (12 pts)

65. (2 pts) According to a study, river-obligate bird species “were associated significantly with the least modified reaches characterized by faster flows, exposed bedrocks, banks with pebbles, [and] boulders with more intact riverine forests” (Sinha et al. 2019). Based on this information, in which areas are river-obligate bird species likely found? Select all that apply.

- a. Areas with extensive natural levees
- b. Areas with relatively straight stream channels
- c. Areas with relatively wide stream channels
- d. Areas with a high-energy depositional environment

The Great Lakes are home to many bird species. Lake levels in the Great Lakes vary on a seasonal and multiannual basis.

66. (2 pts) In the winter, the Great Lakes are regularly subject to sub-freezing air temperatures.

Predict the effect that lower than average winter temperatures would have on lake levels. Briefly justify your answer.

Lake levels would be higher than average (+1 pt). Colder temperatures would increase the ice cover of the lake, reducing evaporation OR colder temperatures reduce the evaporation rate (+1 pt) OR ice is less dense than cold water just above freezing (+0.5 pt, though this effect would be small). *Partial credit: answer is “lower” followed by valid reasoning (e.g., reduced runoff from frozen rivers, less precipitation entering the lake due to ice) (+1 pt)

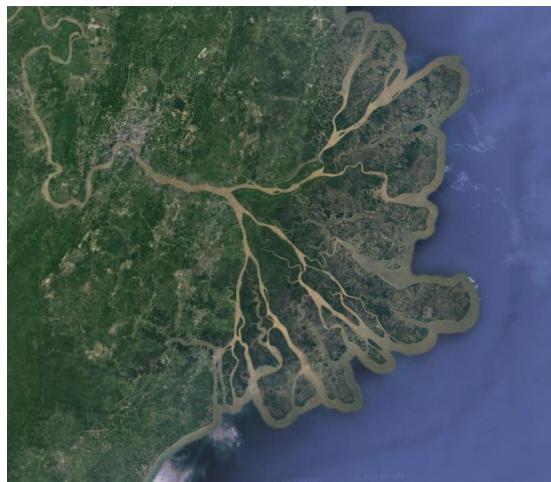
67. (1 pt) Another study (Reske and Yun 2000) found that water levels in the Great Lakes were inversely related with bird species diversity and habitat availability. What effect would above-average winter snowfall alone have on total shoreline diameter and bird species diversity in the following spring?

- a. Increase; increase
- b. Increase; decrease
- c. Decrease; increase
- d. Decrease; decrease

68. (2 pts) A student hypothesizes that dam construction on streams emptying into the Great Lakes would decrease bird species diversity. Briefly explain whether the student's hypothesis is justified, and include the term "base level" in your explanation.

The hypothesis is justified (+0.5 pt). Dam construction would lower the downstream base level, which would promote erosion and habitat loss. (+1.5 pts for a correct statement on base level and for mentioning erosion, +1 pt for either)

Refer to the following image of a delta for questions 69-72.



(Credit: Google Earth)

(0.5 pt each) Based on the image, indicate whether each of the following statements is true or false.

69. The delta can be classified as a "bird foot" delta **false**

70. The delta likely consists of highly angular sediment **false**

71. The smaller streams that the main branch separates into are termed tributaries **false**

72. The delta is a hybrid between river-dominated and tide-dominated **true**

Ducks and geese commonly inhabit wetlands and lakes. However, they can affect the chemical properties of lakes, and they may be negatively affected if their habitats are polluted.

73. (1 pt) Ducks and geese are introduced to a lake and their populations increase. In what ways will this change the lake? Select all that apply.

- a. Overall dissolved oxygen levels in the lake will decrease.
- b. Overall phosphorus levels in the lake will decrease.
- c. If the lake were initially mesotrophic, the lake may become eutrophic.
- d. If the lake were initially eutrophic, the lake may become mesotrophic.

74. (2 pts) Heavy metal contamination of lakes is a significant issue. Select all of the following that are true about heavy metal contamination.

- a. High microplastic concentrations may enhance heavy metal pollution
- b. Heavy metals can be deposited onto surface waters from the atmosphere
- c. Heavy metals can be transported via dissolved load as well as via suspended load
- d. Heavy metals are nearly solely sourced from human-related activities
- e. Lakes with higher pH are more susceptible to heavy metal pollution
- f. Increased lake conductivity may be associated with higher heavy metal concentrations

Section 8: Everyone should lake hydrology (18 pts)

A lake is located in a region with average air temperatures (in °C) of select months shown in the data table below.

| Month | January | April | July | October |
|-----------|---------|-------|------|---------|
| Avg. high | 9 | 18 | 28 | 19 |
| Avg. low | 2 | 9 | 19 | 11 |

75. (1 pt) Which is the most likely classification for the lake?

- a. Warm monomictic
- b. Cold monomictic
- c. Dimictic
- d. Polymictic
- e. Amictic

76. (1 pt) During which month(s) is the thermocline most pronounced? Select all that apply.

- a. January
- b. April
- c. July
- d. October

77. (1 pt) During which month(s) is lake turnover most likely to occur? Select all that apply.

- a. January
- b. April
- c. July
- d. October

The following figures show some possible lake setups; the ovals represent the lake bodies and the arrows represent surface streams flowing into/out of the lake.



Figure A



Figure B



Figure C



Figure D

78. (1 pt) Which figure(s) correspond to an endorheic lake? Select all that apply.

- a. A
- b. B
- c. C
- d. D

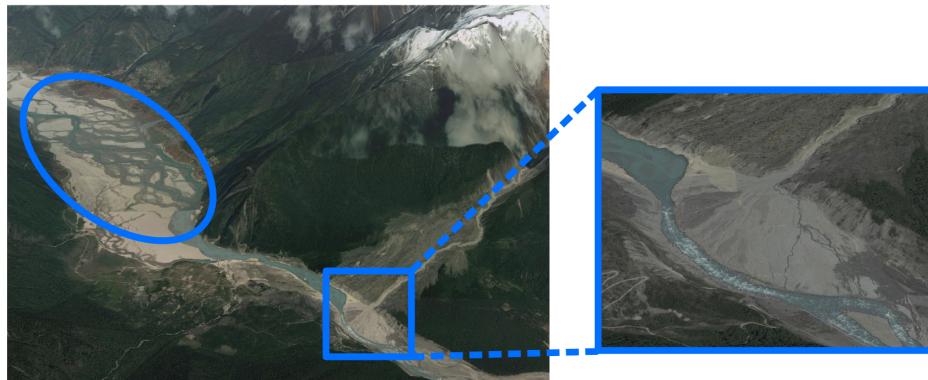
79. (1 pt) Which figure is the most common?

- a. A
- b. B
- c. C
- d. D

80. (2 pts) Which figure best corresponds to a perennial lake located in a region with uniformly impermeable bedrock? Justify your answer.

Figure A (+1 pt), since the lake will have little groundwater inflows/outflows, so will likely be recharged by and discharge into surface waters and streams (+1 pt for either/both reasons or a valid explanation).

The figure below shows the site of a former lake, circled in the photo below.



81. (1 pt) How was this lake probably formed? (A word or phrase is enough)

Landslide/landslide damming

82. (1 pt) What is the channel type encircled in the blue ellipse? (please answer with one word)

Braided

83. (1 pt) Identify the feature that is boxed.

Alluvial fan (+0.5 for just “fan”)

Lakes have multiple physical and chemical properties.

84. (2 pts) Select all the following statements that are true about light levels in a lake.

- a. During the summer, the average intensity of light in a lake is higher.
- b. Light levels generally decrease linearly with depth.
- c. Light availability in lakes is generally greater than light availability in streams.
- d. Agricultural grazing upstream will increase the light availability of a lake.

85. (1.5 pts) Two neighboring lakes, Lake A and Lake B, have the same average depth. Lake A has a larger surface area and length than Lake B. Which lake will have larger waves, on average?

Briefly justify your answer.

Lake A (+0.5 pt). The distance over which the wind blows over Lake A is greater (or wave fetch is greater for Lake A) (+1 pt), so the wind speed will be higher.

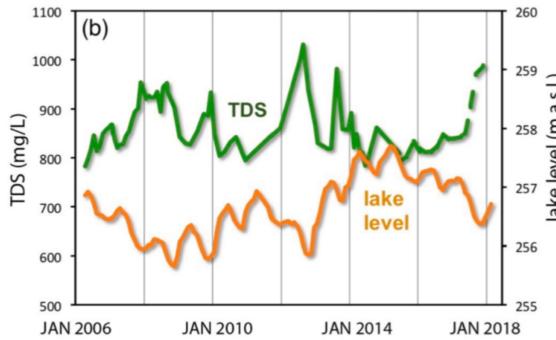
86. (0.5 pts) If two lakes have the same surface area, would mixing be more effective in a shallower or deeper lake?

- a. Shallower
- b. Deeper
- c. Neither; both would have equal mixing

87. (1 pt) Compared to non-tidal waves on a lake, tidal waves generally have a ____ wavelength and a ____ amplitude.

- a. longer; higher
- b. longer; lower
- c. shorter; higher
- d. shorter; lower

88. (1 pt) Consider the following graph of TDS (total dissolved solids) versus lake level.

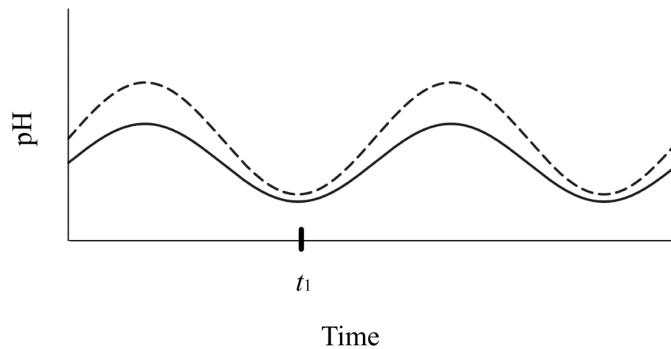


(Frondini et al., 2019)

Which of these statements can be inferred from the graph, if any?

- I. The lake is primarily fed by groundwater rich in ions
 - II. TDS levels are elevated during years with below-normal precipitation
-
- a. I, only
 - b. II, only
 - c. I and II
 - d. Neither

Consider the following graph of pH versus time for a lake with some aquatic plants and algae. The two curves correspond to different layers of the lake.



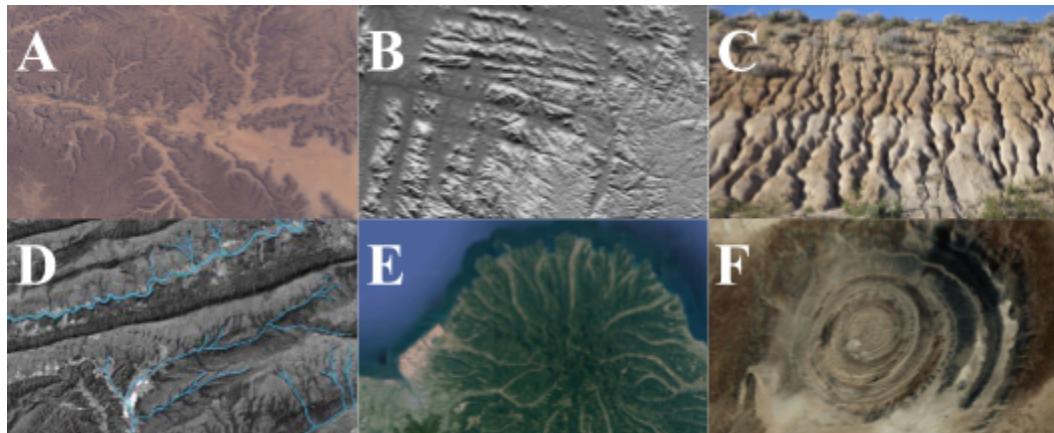
89. (0.5 pt) The period of the graphs is approximately 1 day. During what time of day does time t_1 correspond to?

- a. Early evening
- b. Just before sunrise
- c. Noon

90. (1.5 pt) Does the dotted curve correspond to pH fluctuations in the limnetic zone or profundal zone? Briefly justify your answer.

Limnetic zone (+0.5 pt). Most respiration/photosynthesis takes place in the limnetic or photic zone/upper levels of the lake (so fluctuations in pH are higher), OR the pH decreases slightly with depth in a lake, and the dotted curve (limnetic zone) has a higher average pH than the profundal zone (+1 pt for a valid justification).

Section 9: Drain Age (11 pts)



(0.5 pt each) For questions 91-98, write the **capital letter** of the image corresponding to the following drainage patterns. If the drainage pattern is not among the images, write “N”.

91. Annular **F**

92. Dendritic **A**

93. Parallel **C**

94. Radial **E**

95. Deranged **N**

96. Rectangular **B**

97. Centripetal **N**

98. Trellis **D**

(1 pt each) For questions 99-101, write the capital letter of the image corresponding to the drainage pattern that would form in the described environment. If the drainage pattern is not among the images, write “N”.

99. Nepal’s Kathmandu Valley contains a circular basin where tributaries of the Bagmati River converge. **N**

100. The steep escarpments found in Chambal Valley, Rajasthan are composed of weak substrate that is devoid of vegetation. The landscape that forms from erosion in this region is referred to as badlands topography. C

101. Mount Rainier is an active stratovolcano found in the state of Washington, largely composed of andesite. E

102. (1 pt) Compared to the drainage pattern in Image C, the drainage pattern in Image A tends to form on ___ slopes.

- a. steeper
- b. gentler
- c. equally steep

103. (1 pt) What term would describe a stream that forms a dendritic pattern as it flows through alternating bands of resistant and less-resistant bedrock?

- a. Accordan
- b. Antecedent
- c. Deranged
- d. Divergent
- e. Nonconforming

104. (1 pt) The stream order is ___ at the center of a radial drainage basin and ___ at the center of a centripetal drainage basin.

- a. high, high
- b. high, low
- c. low, high
- d. low, low

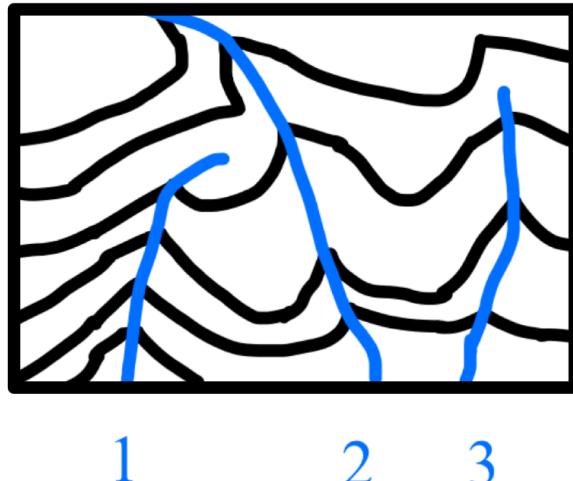
105. (1 pt) A ridge in the North American Cordillera separates the watershed of the Atlantic Ocean from that of the Pacific Ocean. What is the term to describe this type of boundary?
Continental Divide (+0.5 for just “Divide”)

Section 10: Channel 10 News (10 pts)

(0.5 pt each) For questions 106-115, indicate whether the statement is true or false.

106. Water flowing in the hyporheic zone of a stream channel tends to flow faster than it does in the open channel. **False**
107. For an ephemeral stream, the water table is below the stream channel. **True**
108. In a region where a river transitions from flowing over more resistant bedrock to less resistant bedrock, a nickpoint is likely to form after some time. **True**
109. During a flood, the competence of a stream increases while its capacity remains the same. **False**
110. For a meandering stream, the thalweg is closer (in terms of horizontal distance) to the cut bank than the point bar. **True**
111. In a straight channel stream, the greatest flow velocity in a stream tends to be near the bed of the channel. **False**
112. Potholes are often formed in the sections of a stream that exhibit laminar flow. **False**
113. The implementation of flood-control dams would cause the floodplain to erode. **True**
114. As stream velocity increases, sand is usually the first to be eroded before clay. **True**
115. A river system in dynamic equilibrium means that it is not subject to disturbances or perturbations that may affect its flow. **False**
116. (2 pts) [TB7] A student calculates the sinuosity of a certain stream to be 0.45. How can one immediately tell that this value is unreasonable? Why is this answer not physically possible?
The sinuosity of a stream cannot be less than one/must be at least one (+1 pt). The length of the stream between two points can not be shorter than the straight-line distance (+1 pt).

For questions 117-119, consider the following topographic map with numbered streams.



117. (1 pt) Complete the following statement: in the future, stream ___ will be the most likely to capture or pirate stream ___.

- a. 1; 2
- b. 1; 3
- c. 2; 3
- d. 2; 1
- e. 3; 1
- f. 3; 2

118. (1 pt) Briefly justify your answer to the previous question.

Streams extend their length by headward erosion. Stream 1 is steeper/has a higher gradient than Stream 2, so Stream 1 will extend towards Stream 2 and capture its flow upstream. (+1 pt for correctly comparing stream gradients; statement about headward erosion not necessary)

119. (1 pt) Identify the number of drainage divides shown in the map (before stream capture) and after stream capture.

2; 1 (+0.5 pt for each)